Extracting Coherent Structure from High Frequency Ocean Noise

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LONG-TERM GOALS

The central effort of this research will be to develop the appropriate theoretical structure and subsequent processing tools and then to experimentally demonstrate utility of extracting the deterministic acoustical properties of the ocean environment from random noise.

OBJECTIVES

Using theory and experiment, we will study the space-time wavefront coherence properties of surface noise not previously explored. We seek the underlying physics and signal processing methods that ultimately will allow for the extraction of wavefronts representing the time-domain Green's function (TDGF) between noise observation points. An important potential use of the latter results is for inversion.

APPROACH

We intend to demonstrate that the two-point acoustic time domain Green's function (TDGF) can be obtained analogously in the ocean using natural surface noise. The ultimate feasibility of the proposed research is suggested by our work using shipping noise that we briefly review here. In particular, the long-time correlation between a receiver and elements of a vertical array of receivers yields a wavefront arrival structure at the array that is identical to the structure of the TDGF except that the amplitudes of the individual wavefronts are shaded by the directionality of the noise sources. The Green's function emerges from those correlations such that *each noise emission passes through both receivers*. For the ocean environment considered here (there is no significant 3-dimensional multiscattering in the frequency regime of the available data), only surface sources aligned along the horizontal line between the receivers can contribute over a long-time correlation.

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WORK COMPLETED

We have completed our analysis of noise data of opportunity given to us by the NPAL group. We have also completed a shallow water theoretical demonstration. A central issue that already arose in the research was the relation between this process and more conventional correlation beamforming methods. We successfully conducted a small experiment to clarify this relation. We have submitted a manuscript on the work completed

RESULTS

Theoretical demonstration of the noise correlation process in shallow water. The theory predicts that the temporal correlation process between two hydrophones yields the TDGF but shaded as a dipole. Figure 1 shows the configuration for which a theoretical simulation has been performed

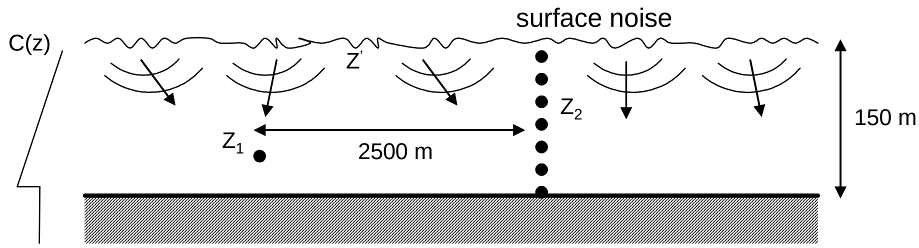

Figure 1. Geometry for TDGF and noise correlation process.

Figure 2 shows the results of the computations. The upper panel is a simulation of the temporal correlation between the single receiver on the left in Figure 1 and the array. The middle panel is a direct simulation of the TDGF while the lower panel is a dipole amplitude shading of the TDGF of the middle panel. Notice how the upper and lower panels show the same amplitude structure while all the panels show the same arrival structure. This is in agreement with theory.

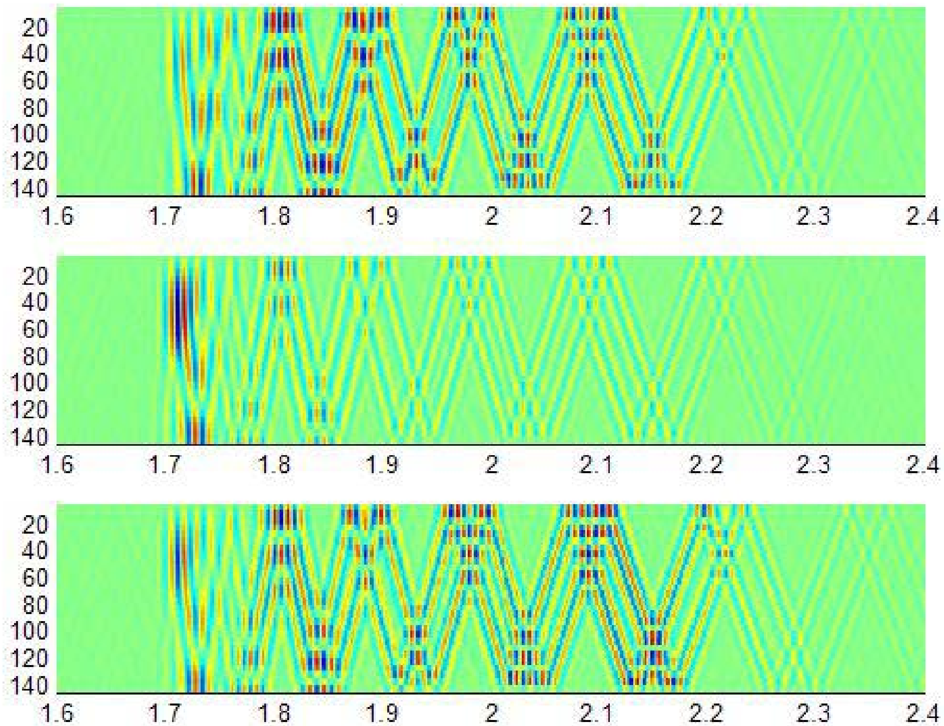

Figure 2. Simulations for the geometry in Figure 1 with the vertical axis depth along the array and horizontal axis time. Upper Panel: Noise correlation process. Middle Panel: Direct simulation of the TDGF. Lower Panel: Dipole shaded TDGF.

Analysis of NPAL data. This data was provide by the NPAL group. Noise data from four arrays were used when the source was not turned on. The noise is actually of ship origin. Our manuscript derives the similarity of the long time ship noise correlation process with the correlation of surface noise. Basically, as shown in Figure 3, it is the contribution from sources in the endfire lobes that contribute to the build-up of the TDGF. The left lower panel shows the symmetric time of arrival structure that we predict would exist while the lower panels show the lack of results when correlating noise data from unrelated time intervals.

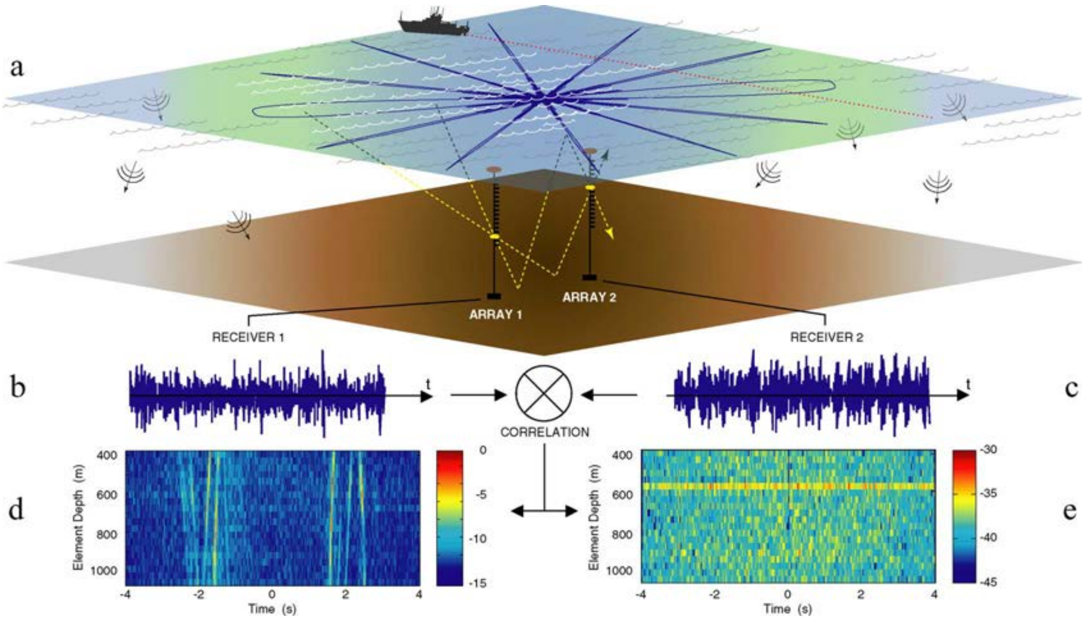

Figure 3. The NPAL setup and an example of the processed data.

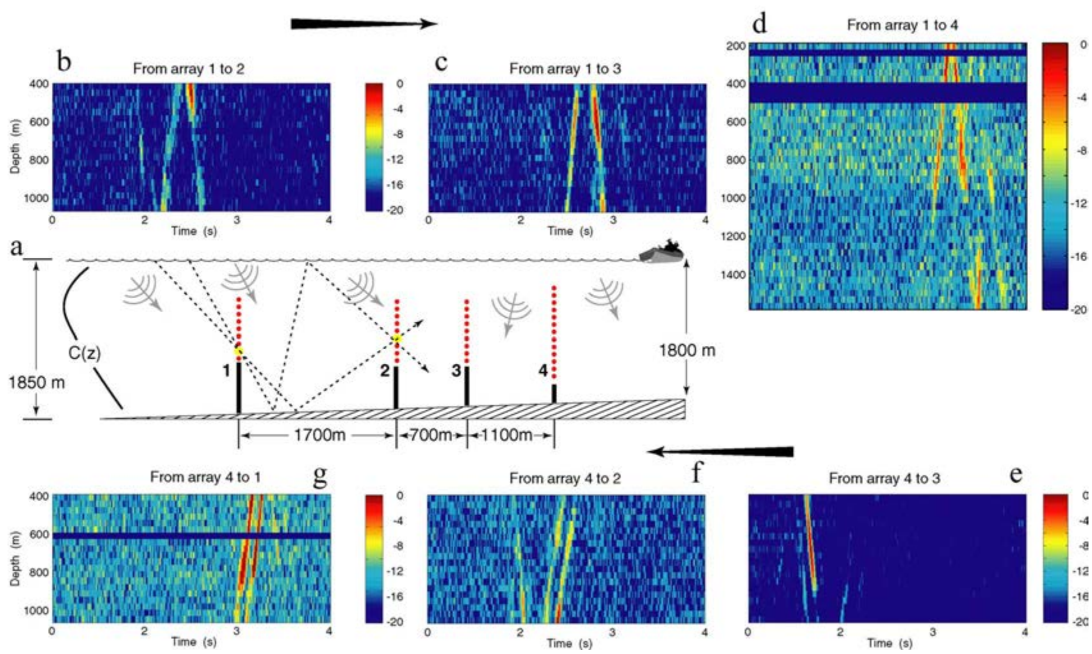

Figure 4. NPAL results for multi-array correlations.

Figure 4 shows The NPAL noise data processed between one receiver and three arrays showing the actual progression of a traveling wavefront structure. The opposite correlation process produces wavefronts traveling to the left as expected and is shown in the lower panels.

Correlation beamforming experiment. Theory predicted that the long time correlation process would average down correlation receptions except in the enfire direction. Figure 5 shows the results of a two-

sonobuoy correlation experiment with the path of the ship shown in the upper panel oriented with respect to the main lobe. The lower panels indicate progressively the results for increased correlation times showing that, indeed, the long-time correlation accumulates in the endfire direction.

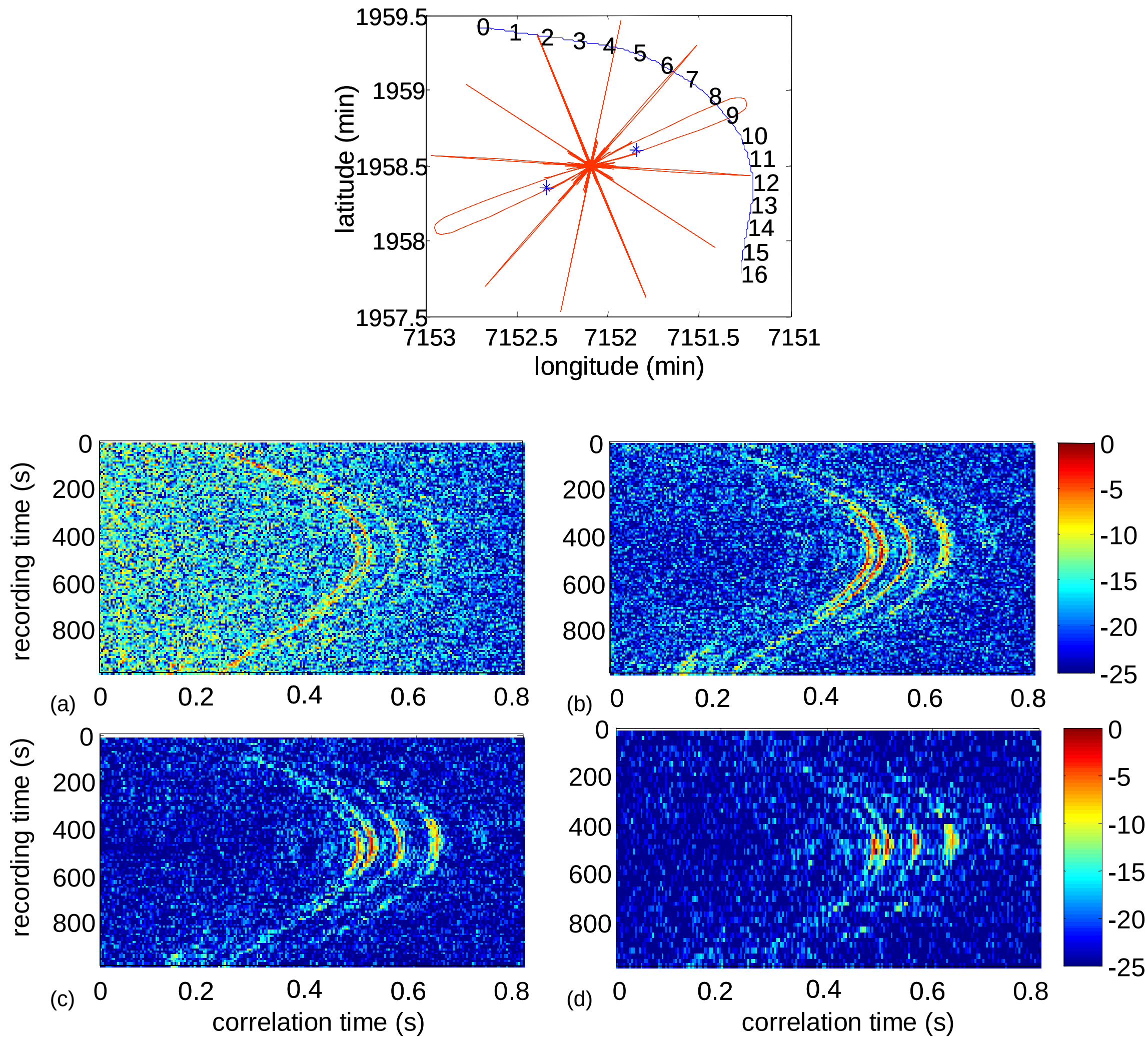

Figure 5. Sonobuoy correlation beamforming experiment.

IMPACT / APPLICATIONS

Inversion techniques for the estimation of waveguide characteristics are of general interest and facilitate the prediction of system performance. Natural transition paths for these results will be SPAWAR (PMW-155) and NAVSEA (ASTO).

RELATED PROJECTS

We have used data from the NPAL program. Furthermore, this program is related to the Time Reversal Acoustics program in that these same Green's functions may be used to demonstrate the time reversal process.

PUBLICATIONS

Philippe Roux,W.A. Kuperman, and the NPAL Group, "Extracting coherent wavefronts from acoustic ambient noise in the ocean," J. Acoust. Soc. Am. (2003). [submitted]